AIRCRAFT

ABSTRACT

The United States aircraft industry is one of the essential foundations of the economic, political, and military elements of U.S. national power. But with the recent events such as the war with Iraq, the Severe Acute Respiratory Syndrome (SARS) outbreak, some major carriers filing for bankruptcy protection and with the 2nd anniversary of September 11th disaster steadily approaching, the uncertainty in this industry continues, particularly in terms of market recovery. Still leading U.S. business in export dollars, the industry has been forced to look for new markets as worldwide commercial aircraft sales continue to drop. For the first time, Europe has taken over the commercial market in total aircraft sales for 2003. One area that is still prospering is the military market. The U.S. has done well in this area and it appears now that Europe wants a piece of the action. It is becoming clear that in order to grow their businesses both the U.S. and Europe will have to partner with others to gain additional market share. Based on this outcome it appears that this industry will continue to do well in an uncertain future.

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INTRODUCTION

Still feeling the after affects of 9/11, the aircraft industry remains a major player in the world economy. Even though they remain a player, according to John May, President and Chief Executive of the Air Transport Association (ATA), "The state of the airline industry today is somewhat dire. Since 9/11, the airline industry has lost $18 billion before the hostilities ever started in Iraq and future losses for 2003 are being projected at $6.7 billion."[1] But, there has been tremendous growth in the military market. Both the U.S and Europe are going after this market of opportunity.

To meet the economic reality of the past two years, air carriers are cutting tens of billions of dollars in expenses, have laid off 100,000 employees and have taken several hundred aircraft out of service.[2] The bottom line is that the September 11, 2001, attacks, a weak economy, the war in Iraq and a deadly pneumonia virus (SARS) have resulted in low demand for airline tickets in what several executives referred to as the "perfect storm" now blowing through the aviation market.

With this information many questions remain: Will there be a long-term, fundamental change in the industry? Will the predictions of recovery in 2003 hold true? When, if ever, will the industry return to the way it was before September 11?

Despite these downward sloping trends, the aircraft industry continues to be a leader in high technology. Unmanned aerial vehicles, supersonic and stealth capabilities and tilt rotor development top a long list of U.S. accomplishments that the aircraft industry has brought to fruition.

This report focuses on four sectors of the aircraft industry: commercial transport and cargo aircraft; military fixed-wing aircraft; rotorcraft (helicopters and tilt rotor aircraft); and aircraft jet engines. Two companies dominate the commercial aircraft business, Boeing and Airbus. Four companies dominate the military fixed-wing market, Boeing, Lockheed Martin, BAE Systems, and European Aeronautic Defence and Space Company (EADS). The rotorcraft segment consists of the three dominant U.S. manufacturers, Bell Helicopter (Textron), Boeing, and Sikorsky Aircraft (United Technology Corporation) and their two principal European competitors, EADS Eurocopter (a partnership of Germany and France) and Agusta Westland (a partnership of Italy and the United Kingdom). The four primary international aircraft engine producers are paired into two U.S. companies, General Electric (GE) and Pratt & Whitney (P&W), and two European companies, SNECMA in France, and Rolls-Royce in the United Kingdom, which includes Rolls-Royce Allison in the U.S.

COMMERCIAL FIXED-WING AIRCRAFT

For the purposes of this report, commercial fixed-wing aircraft include medium and large passenger and cargo aircraft of greater than 100-passenger capacity.

Current Condition. The current jet transport market is certainly one of the most challenging the world's large aircraft manufactures have ever faced. Demand for jets is down because the airline traffic and air carrier profitability have dropped precipitously. In addition, market structures are rapidly changing due to the growth of discount carriers at the expense of the traditional major airlines. This weak and transforming market for large jets comes at a time when the two manufacturers in this segment, Boeing and Airbus, are engaged in an ever-aggressive battle over market share that has further degraded both combatants profitability.

The decline in demand that is affecting this sector reflects general conditions in the broader economy and a clear post 9/11 public disinclination to travel by air, which together only compounds the changes occurring within the airline industry itself. The effects of very low demand combined with the aggressive competition within the jet transport-manufacturing

segment should not be surprising. Net orders in 2002 were 551 aircraft, essentially flat from the 546 in 2001, and significantly down from 1,081 in 2000.[3] Total airliner production for 2002 was 683, with Boeing producing 380 aircraft[4] and Airbus 303.[5] This contrasts with 2001 total production of 852 aircraft.[6] Projections for total deliveries in 2003 are 575, with 300 and 275 projected for Airbus and Boeing respectively.[7] Output in 2004 is expected to further decline to 511 aircraft.[8]

While both manufacturers have been hit hard by the slowdown in the market for transport aircraft, Boeing has had to reduce production from high levels, while Airbus has been able to cope more easily, given that its recently rising production levels have fallen off only slightly. Since 9/11, the workforce in Boeing's commercial airplane division has been reduced by 30,000 people, to about 63,000.[9] In 2002, Boeing deliveries decreased 28% and revenues fell 19%.[10] Boeing Commercial Airplane's operating earnings fell from $2.8B in 2001 to $2B in 2002.[11] At the same time, its operating margin fell from 8% to 7.1%.[12] Though perhaps less severely, Airbus is feeling the pain too. Its sales in 2002 fell 5% to $19.2B down from $20.5B in 2001,[13] with operating profits sinking as much as 30% to $1.1B.[14] In contrast to the massive layoffs at Boeing, Airbus has laid off only a few hundred workers this year from its workforce of 45,000.[15] However, Airbus hires many temporary workers to avoid tough European anti-layoff laws. In 2002, Airbus reported it had cut the equivalent of 5,000 jobs by dropping temporary and part-time workers.[16]

Despite this dismal picture, both manufacturers should be able to survive through this difficult time, mitigated in part with their current backlog of orders. At the end of 2002, Airbus had an order backlog of 1,470 aircraft compared with Boeing's 1,152[17] worth a combined $172B.[18] If indeed production in 2003 is in the range of 575-600 aircraft and the projections for 511 in 2004 are accurate, this would be the mildest down cycle in recent jetliner history. The low point of the last down cycle was 1995, when 379 planes were delivered and the low point of the down cycle before that was in 1984, when 244 planes were delivered.[19] Given the current situation in the airline industry, the best chances for new orders seem confined to a few purchases by low-cost airlines. Therefore, the main avenue for continued production is in building down the existing backlog.

However, the more closely the backlog numbers are evaluated, the more undependable they appear. Many sales made to airlines over the big sales years of 1997-2000 were accompanied by lenient cancellation or deferral terms. Cutbacks announced at American, United, and US Airways suggest that many airlines will exercise this flexibility to defer orders in response to their own problems. Therefore, it is likely that much of the backlog will be deferred for delivery to the latter part of the decade.

In the U.S., SouthWest Airlines has been the pioneer low-cost carrier, now however, others have followed the pattern of discount point-to-point travel between secondary airfields. As these discount carriers have grown, their expansion has come at the expense of the major carriers. Therefore, orders from low-cost carriers are less about growing the market for new jetliners and more about redistributing it to meet the demands of the successful carriers with lower cost bases.[20] Currently, Airbus and Boeing face key challenges as they strive to determine how to profitably compete in markets that are demanding products that will provide greater operational efficiency.

Challenges. Because the aircraft and airline industries are so closely aligned, the current aircraft industry challenges for the foreseeable future are linked to airline profitability. The aircraft industry's challenges also extend to lack of sales and a glut of aircraft on the market. Finally, Boeing will be challenged by competition from an increasingly powerful Airbus Corporation.

Even prior to the terrorist attacks in 2001, the airlines were being greatly impacted by the downturn in the economy. Had there been no "9/11," the economy still would have been a great obstacle to the significant growth seen in the 90's. The attacks on the World Trade Center exacerbated the decline of the airline and aircraft industries.

The biggest hindrance to airline profitability was the slow down of business travel in 2000. Business travel had been the mainstay of the top four major airlines. But with a downturn in the economy, many businesses turned away from face-to-face meetings to alternate means of business communication. The majors such as American and United counted on covering the cost of their substantial hub operations with the revenue they had come to expect in the 90's from a boom in business reservations. Business travelers seeking maximum flexibility would pay substantially more for transferable tickets, flights out of large conveniently located hubs (such as LAX) and a large choice of flight schedules. The cost of such operation was more than paid for with the generous premiums made on business tickets. The major airlines were willing to pay increasingly exorbitant labor costs and increased benefit packages due to their large profits. In the U.S., according to the Air Transportation Association, compensation cost per employee, including wages and fringe benefits, increased from $50,000 a year in 1991 to nearly $80,000 in 2002.[21] However, the downturn in the economy caught the majors with too much overhead and not enough business travelers. Consequently, most of the majors are near or in Chapter 11 bankruptcy.

The majors were severely hurt by the drop off in business travel, and then were critically wounded by the bourgeoning costs of post "9/11" security measures required by recent Homeland Defense measures. As the recently dismissed CEO of American Airlines, Donald Carty, said, "What is troubling to us today is the fact that while we as an industry are feverishly working to reduce costs, government actions, however well-intentioned, are pushing our cause the other way.[22]" Security taxes mandated in 2002 to help pay for security initiatives are being absorbed by the airlines. Lost revenue on U.S. mail carriage and other expenses such as cockpit door reinforcement, lost seat revenue for sky marshals and other security costs are further hurting airline profitability.

Delta Airlines CEO Leo Mullin estimates that such disparate measures have combined to cost Delta $660 million this year alone.[23] The security measures required of the industry cost over $4 billion, and that may very well be matched by lost passenger revenue due to hassles in airport security. Of course, these are direct costs to the industry.

Indirectly the airlines and the aircraft industry fear that they will not attract investors. No investor wants to finance an aircraft lease or purchase when they can invest in more lucrative endeavors elsewhere. Indeed, many airlines would prefer to finance deliveries with leveraged leases, but investors are unwilling to take those risks on leased aircraft. The supply of leased equity is down 75%, according to lease arranger estimates. As Steven Josselson reports in the Air Finance Journal, the U.S. airline industry has lost more than $15 billion between 9/11 and today.[24] Such losses do not attract investors to aircraft purchase or the airline industry in general. Because investors are less likely to put money into leveraged leasing of aircraft, manufacturers are stepping up their support of the airlines and the leasers by negotiating favorable lease terms themselves. Both Boeing and Airbus are heavily involved in manufacturer support with loans, lease financing and residual value guarantees.[25]

One thing that hasn't been reduced as a result of the waning economy and the residual of terrorist fear is a glut on the used aircraft market. As of late last year 1/5 of the U.S. passenger fleet had been grounded. Furthermore, used jet prices are down 40% - 80%. As more of the major airlines declare financial troubles we can expect even more aircraft on the used market, further depressing prices. Consequently, there are over 2,000 aircraft currently sitting in

California's Mojave Desert aircraft graveyard. This all means that Boeing probably won't be making large numbers of aircraft anytime soon.

That does not bode well in the fight for world market share. In fact, Airbus is now selling more commercial aircraft than Boeing based on ordering data. By the orders metric, Airbus won the 2002 contest with 300 orders compared to Boeing's 251.[26] Deliveries however, remain in Boeing's favor, with deliveries in 2001 coming to 34.9% for Airbus and 65.1% for Boeing (by value).[27] In 2002, Airbus delivered 303 aircraft, while Boeing delivered 380 continuing its leadership in deliveries. While it appears Airbus will build more aircraft in 2003 than will Boeing, in terms of numbers of aircraft, the value of Boeing's deliveries that year should mean it will continue to out sell Airbus, with a 53.8% share by value.[28]

It appears that Airbus has begun to gain the upper hand in the battle for control of market share in fixed wing commercial aircraft. It forecasts that it will deliver about 300 aircraft in 2003, setting it on course to be the market leader in terms of orders, ahead of Boeing. Boeing on the other hand, cites the fact that aircraft ordered or built do not equal aircraft delivered. Airbus "sold" 300 aircraft last year, but received 67 cancellations.[29] Nonetheless, Airbus states that it has more than 1,500 orders in backlog, which means the company could maintain production at current levels for 2003.

The ongoing battle for market share will cause both Boeing and Airbus to reevaluate their customers, and how those customers will operate. It is clear that all airlines will need more economical and efficient aircraft. But there is some question as to how those aircraft will be operated. It could be argued that discount airlines are the only profitable carriers at this time, and should be the model for future aircraft design.

Discount airlines such as SouthWest and EasyJet make their money by operating with tight monetary control. They operate out of secondary fields near major population centers, which cuts down leasing costs and speeds operation in less densely flown patterns. They understand that time in the holding pattern and on the ground is lost revenue, and so turn their aircraft around in 20 minutes or less.[30] Their flights are no-frills, and don't have business-class or first class service. They provide the cheapest travel fares, and advertise frequent flights on the most heavily flown routes. They maximize their profit potential by flying routes that optimize the fuel burn profile of their chosen aircraft. Because of this, all successful discount airlines operate smaller aircraft (such as the A319 and the B737) at the limits of their flight profile. Scheduling more flights on smaller aircraft is tough logistically, but yields more revenue if the flights remain mostly full. They don't operate large costly hubs like the majors, but rather, rely on tight scheduling and outsourcing of heavy maintenance on demand. And importantly for the aircraft industry, the discount airlines utilize only one type of aircraft to keep maintenance costs low – a plus for future sales. The discount model would require a 200-300 seat aircraft capable of flying coast to coast with FAA stipulated reserve fuel. The model would also require a rugged design to withstand near constant flying, along with engines providing longer time between maintenance and overhaul. And of course, they must offer efficiencies greater than the airlines now enjoy with their current fleets.

However, the discount airline model will never replace the need for long distance flights. There will always be a need for transcontinental aircraft. In order to make these types of aircraft economical it only makes sense that they will fly longer distances, with fewer sorties, and hold more paying customers. They, too, must provide greater efficiency than their current fleets. The Boeing 747 has long dominated the long distance market and continues to provide value. But it could be challenged by a newer, more profitable wide-body.

So the aircraft industry faces the challenge of choosing just what type of aircraft to build, given that they can't afford to build more than one. The choices they make may well decide which producer will be the market leader for the next decade.

Outlook. Based on the dire state that most air carriers are in, it is evident that low demand for transport aircraft will continue at least into 2005. The recovery will be slowed by a number of factors, not the least of which is the poor financial condition of the airline industry, the return of stored aircraft to service, reduced air travel due to geopolitical uncertainty, and a changing market for business travelers. While both Boeing and Airbus have been hurt by the low demand for their products, both can manage in the short run as they work off backlogged orders. As bad as the situation has been, especially for Boeing in terms of employment cuts, this has been a relatively mild downturn for these manufacturers, which will still build over 500 aircraft this year.

Even in a market dominated by economic decline and terrorist overhead, the world's two major commercial aircraft makers are in dire competition for market share. In a strange twist of fate, Airbus (who broke into the market with smaller aircraft while Boeing dominated the market with wide-bodies) is touting the virtues of the 550-seat A380 jumbo jet. Boeing on the other hand, believes that the market is ready for its 7E7 long-range aircraft that can carry 200-250 passengers. Boeing sees a 100-seat gap between Airbus's A320 and A330-200 that it believes its new 7E7 aircraft can fill.

It is becoming evident that developing nations such as China are the next big market for commercial aircraft. This fact has not been lost on Boeing or Airbus. China's state run airlines are in the midst of a government-mandated consolidation aimed at making them larger. What that means to the aircraft industry is that the Chinese carriers are expected to buy 1,900 new planes during the next 20 years.[31] That would be 10% of the total world market according to Airbus. As China's airlines are consolidated, there is a potential for big profits by either or both major aircraft manufacturers.

Boeing and Airbus must determine how to best serve the restructured airline industry of the future. It seems reasonable to look at the discount airlines such as SouthWest, JetBlue, and AirTran at least for continental travel, as the accepted airline business model for the future. Indeed, many of the major carriers are looking to start up their own discount airlines to cash in on the new business model. Therefore, it is less likely that a single airline will continue to fly a diverse number of aircraft. This suggests a long-term relationship between manufacturer and airline built on a single platform or very a small similarly configured family of aircraft. It appears that the airlines will strive for greater frequency between point-to-point city pairs.

Airbus has long been interested in establishing a major facility in the United States to expand its reach into both commercial and military markets. Jean-Louis Gergorin, EADS executive vice president for strategy told Defense Daily International, "If we want to penetrate the U.S. market, we must consider teaming with an American partner.[32]" The idea is that Airbus would team with a company such as Lockheed, Raytheon or Northrop to establish a facility in the U.S. to produce military derivatives of the Airbus aircraft. Once established, the facility could also perform final assembly for Airbus commercial jetliners. For Boeing, an alliance between Airbus and a leading U.S. company constitutes a real competitive threat. Boeing differentiates itself in the market by being a U.S. company. If Airbus could be manufactured in the states, it would effectively take away that differentiation.

Boeing believes this will keep demand strong for both regional jets and intermediate twin aisle airliners as well, with less growth in the 747-size market. Airbus, on the other hand, is betting on growth in the large airliner market with its investment in the new A380 to relieve the congestion at the world's major international airports. It has already collected nearly 100 orders

for the passenger and freighter versions of the A380. The gamble is that there will be enough demand over the next twenty years to recoup their tremendous research and development investment … and that a more fuel efficient 747 will not dilute the jumbo market further.

For now, the intense competition in the industry will continue across all market segments, with Boeing and Airbus finding themselves in roughly a parity situation overall. Perhaps the biggest question for Boeing is whether it can use the strategy of avoiding large investments in new developmental programs and remain competitive in the long haul. The reaction of the market to the proposed 7E7 will provide some indication if this strategy will be successful. It is possible that each manufacturer will eventually choose to specialize in serving some segment of the airline market instead of attempting to be all things in all markets. By pursuing such a strategy, both firms could assume their strongest position in the market, allowing for a less direct competition and affording them greater pricing power and profitability. This may not necessarily be good news for cash-strapped airline customers and low-fare hungry passengers, who have previously benefited from the intense competition between the two industry giants. In the near term, however, we should expect both firms to continue the strong head-to-head competition, even as they struggle to anticipate the needs of a transforming market.

MILITARY FIXED-WING AIRCRAFT

The military, fixed-wing sector of the aircraft industry includes strike, fighter, bomber, air mobility (transport), special-mission, unmanned air vehicles and trainer aircraft designed, built or modified for military unique mission requirements.

Current Condition. World military aircraft production fell to its lowest level in 50 years in 2001; however, total U.S. military aircraft sales rose $1 billion to $35 billion in 2001, solely on domestic funding. Manufacturers delivered 325 aircraft with 46 percent exported to non-US customers; however, the number of military aircraft exported declined for the fourth year in a row, down 24 percent. The number exported via the Foreign Military Sales (FMS) program fell to 22, the lowest level on record.[33] The market overall can only be currently described as stagnant.

However, the Global War on Terrorism (GWOT), recent conflicts in Afghanistan and Iraq and a subsequent increase in US defense spending provide security for many current and future military fixed-wing programs. The FY2004 budget is an increase of four percent over the 2003 budget, which also experienced a 14 percent rise above the 2002 budget. Programs such as the F/A-22, the F-35 Joint Strike Fighter (JSF), unmanned air vehicles (UAVs) and transport aircraft have been given increased political and financial stability. Nevertheless, the US fighter inventory has reached an unprecedented age. Even with large funding increases, the USAF fighter fleet age does not decline until the JSF is IOC, and is actually purchased in significant quantities so older aircraft can be retired. Any delay in JSF IOC, and/or a reduction in the F-22 buy, still portends a tactical air "train wreck" impacting the USAF the most severely.

The projected Air Force fighter modernization and recapitalization plans have several major problems. First, under current plans, the USAF is not buying the required quantity of fighters to replace an ever-aging fleet. Second, current plans do not replace aircraft soon enough before projected retirement of the current force structure either by age restrictions or by total hours on the airframe. Additionally, as operations and support costs escalate because of aging aircraft, it may be necessary to replace these aircraft sooner from both an operational and cost effectiveness perspective resulting in a potential "modernization death spiral."

The US export market looks more secure with eight nations signing up with the US to enter the JSF System Development and Demonstration (SDD) phase of the program. Two additional countries have signed on separate to the SDD agreement. Although the aircraft has an IOC of circa 2011 domestically, and 2014 for the export version, the aircraft is becoming the fighter of choice both domestically and internationally. This is having the effect of rationalizing the US manufacturing sector and closing the window of opportunity for European fighter aircraft. However, in the interim, European domestic procurement of fighter aircraft is estimated to double over the period 2000 to 2004.

In the US, Lockheed Martin, the industry leader in military aircraft, is on the way to becoming the sole provider of tactical fighters with the F/A-22 and the JSF. In the interim, production of F-16, F-15 and F/A-18E/F aircraft continues to fill the gap until they become available. In the short term this is contributing to the current overcapacity in the sector. In the transport market, Lockheed Martin and Boeing continue to dominate the market with the C-130 and the C-17 respectively. Northrop Grumman continues to consolidate their core business in systems having ceded platform development, with the exception of UAVs, to Boeing and Lockheed Martin.

Consolidation and collaboration in the sector continues. The Northrop Grumman takeover of TRW in March 2003 further consolidated the industry and establishes Northrop Grumman as a system designer and integrator. Boeing, having lost the JSF program to Lockheed Martin, is conceding the tactical fighter market and focusing on UAV/UCAV development and continuing to seek additional contracts for the C-17 and KC-767. Collaboration domestically (on the F/A-22 which is not being offered internationally) and internationally (on the JSF, Eurofighter, and Gripen) highlights the industry's approach to distributing manufacturing responsibility and on cost sharing. BAe, which has an interest in the JSF, Eurofighter and Gripen, is a prime example of this increased global collaboration.

The focus on military transformation and network-centric warfare (NCW) continues to influence the industry's priorities and direction. The focus by the US in particular on an integrated, coordinated approach is driving interoperability and focusing technology advancements. It is also serving to focus the market on not only US platforms but also on US training, doctrine and associated weapons systems. This is at the expense of overseas competitors who are increasingly falling behind the US in these areas.

Increased competitiveness in the industry, cost constraints and changing culture is driving industry to a 'lean' manufacturing approach. Refined processes, desire for lower costs, schedule constraints and an inclusive company culture are significant issues for companies as they strive to adopt modern management and manufacturing techniques. Technology is increasingly being used to reduce overheads, increase flexibility in configuration options and reduce production times.

The aerospace manufacturing segment currently employs the lowest number of people since 1953 and the demographic shift to an aging workforce, of which many face imminent retirement, is also of increasing concern. These concerns have led its trade association, the Aerospace Industries Association of America (AIA), to recommend government support recommendations made by the President's Future of the U.S. Aerospace Commission (Aerospace Commission).[35]

Challenges. Future challenges within the sector lie in market share and a collaborative approach, industry capacity, the impact of technology and transformation, and the workforce. The most important future fighter procurements are in Europe, placing pressure on European manufacture to maximize the available benefits prior to the US closing the window of opportunity with future platforms. However, budget difficulties have resulted in several deferred

procurement programs recently (Greece and the Czech Republic), while a number of countries have reduced their orders for aircraft.[36]

Germany has reduced the order for Eurofighter aircraft and there is speculation that the UK will also reduce its Tranche 3 buy. Overall, opportunities in the world market are promising with many nations reconsidering either interim procurement of current US produced fighters or delaying procurement until the JSF is available. Similar opportunities exist in the transport sector. Germany has reduced its order for A400M aircraft and only recently approved the buy. This delay in reaching a final decision and the $120 million price tag has led potential customers to either cancel or defer their decision. Financial and technical challenges confront companies in the special mission aircraft and UAV markets.

As U.S. production eventually focuses on the F-35 beyond 2014, Lockheed Martin will become the only manned fighter manufacturer while Boeing focuses on other sectors such as UCAVs and transports. Therefore, the U.S. capacity to surge in manned aircraft production will be dependant upon Lockheed Martin's post-2014 plant and tooling capacity on the JSF line and Lockheed Martin's and Boeing's transport lines. The USAF will also increasingly partner with industry to help meet surge requirements. Northrop Grumman is increasingly focusing on collaboration with either Boeing or Lockheed Martin as a system integrator and this rationalization will place pressure on companies to win contacts in their niche areas as companies narrow their focus over the next decade and place increased emphasis on collaboration.

The consolidation within the industry has also highlighted the increasing dependence on information technology at both the management level as well as on the factory floor. A number of companies acknowledge the requirement to integrate all their business divisions and accept it will take time; however, many still struggle to identify a corporate approach in an era that is increasingly dependant on timely communication internally or between business divisions and partners overseas to achieve lower development and production times and costs.

Transformation, advanced technology and network-centric warfare (NCW) will continue to provide challenges not only to individual companies but also to national strategies. Congress and the DoD continue to emphasize the requirement to transform its military capability to meet future threats and this will continue to influence future force structure and the extent of industry participation. The US focus and emphasis on these issues are consolidating US dominance but also raise budget, schedule and technical challenges. They also place potential customers in a position where they are influenced in their ability to operate in a coalition with the US or be competitive operationally. This may well influence the number of future prime contractors in Europe as European companies lag behind the US in R&D for a follow-on next generation fighter or in high technology areas such as special mission aircraft and UAVs.

Human and intellectual capital is the industry's most valuable resource. However, the industry is experiencing difficulties recruiting and training skilled professionals at a time when the emphasis and future trend is towards complex platforms and high technology systems. As a result, there has been a significant loss of knowledge and expertise within the workforce and the industry. The aerospace industry has also experienced a demographic shift leading to a higher average age of its engineer workforce of 54 years and it's blue-collar workforce of 51 years.[37] This will continue to impact on design, development and production of fixed-wing military aircraft, and is a serious challenge for the industry as a whole. A highly skilled, stable and sustainable workforce is essential to national security and improving economic prosperity.[38]

Outlook. There are encouraging signs in the fixed-wing military aircraft market. This year the fighter market is experiencing its best year since 1999 and the current growth trend is predicted to continue with US and European domestic procurements leading the way. By 2007,

the market will reach a post-Cold War peak with deliveries reaching an estimated $15.6 billion. Over the period 2003 to 2012, production is forecast at 2,961 fighters worth $142.2 billion (Yr2003), a growth of 40 percent. European share of the market will grow an estimated 29.8 percent over the same period.[39]

The chances of a US tactical air 'train wreck' still portend even with large increases in US defense spending and increased emphasis on air power as a result of recent operations. Funding for the F/A-22, F/A-18E/F and JSF has been further consolidated; however, this does not preclude further delays in any of these programs. The success of the JSF program, unique in its level and scope of overseas customer participation, coupled with a deliberate US effort to lead the next generation fighter market, will enable US industry to dominate this market after 2014.[40] Similarly, Boeing and Lockheed Martin are expected to attain 90 percent of the transport market in terms of dollar value out to 2011.[41] The successful launch of the A400M, with an IOC of 2009, may reduce US dominance in this sector.

The special mission sector has traditionally been the last to receive priority and funding. Programs such as the Joint Surveillance Target Attack Radar Systems (JSTARS), the Multi-mission Maritime Aircraft (MMA) and the Multisensor Command and Control Aircraft (MC2A) development highlight the increased focus on these capabilities; however, it is increasingly becoming a US dominated market. The cost of these platforms, combined with requirements for small numbers of platforms, will see a number of customers seek smaller, less capable platforms from a range of world-wide manufacturers. Australia's and Turkey's[42] purchase of a US solution using a B737 fitted with a Multirole Electronically-Scanned Array (MESA) radar to fulfill the AEW&C role and Brazil and Greece's orders for the Swedish developed Erieye AEW capability are examples of this downscaling.[43]

The bomber market will continue to show signs of decline and lack of growth. Plans call for maintaining the current US fleet until the next bomber comes into service in approximately 2020 resulting in the average age of the bomber fleet increasing to more than 45 years.[44] The health of the bomber fleet is dependent on the engine upgrade to the B-52 and modifications to the B-1 and B-2 fleets. The B-1B fleet is planned to be reduced from 93 to 60 aircraft with savings to be reinvested in the remaining aircraft.[45] R&D for the follow-on bomber will include UAV technology.[46] Future AAR tankers will be off-the-shelf derivatives of commercial jetliners. A total of 100 Boeing's KC-767 will be leased by the USAF, with deliveries over the period 2006 to 2011.[47] The unprecedented KC-135 aging issues continue to pose significant risk for the tanker fleet—even after the retirement of all E models and the leasing of 100 KC-767s. From a recapitalization standpoint, the current modernization plan (100 KC-767s) is **only a stop-gap plan at best** because it does not stop or significantly reverse the overall average age towards the CSAF recommended average and maximum ages; nor does it include any plans past the 2012 timeframe.[48] Worldwide alternatives include an Airbus proposed solution with the European Air Group likely to share their airlift and AAR tanker fleets leading to a significant market for new or used Airbuses.[49]

UAVs will increasingly take a share of the special mission market, particularly in the C4ISR roles. However, they are not expected to replace manned platforms for most of these missions, instead they will supplement them and provide increased connectivity in a developing network-centric environment. Global Hawk and the Predator development has been accelerated and their roles refined in recent operations and a number of C4ISR and SIGINT roles could be transferred to UAVs, in particular, the Global Hawk. UCAV development in the form of Boeing's X-45 and Northrop Grumman's X-47 will continue over the next decade with little corresponding development outside the US. However, full production is not anticipated in the next decade.[50]

While industry employment has steadily fallen, demand for engineers and technical workers remains. Increasing dependence and reliance on the application of information technology, lean manufacturing and production techniques along with advanced technology is what is driving the industry association to seek US Government support for the Aerospace Commission recommendations and implementation alternatives to meet the future demands of the industry.[51]

The fixed-wing military aircraft market is increasingly influenced by the US and worldwide emphasis on a NCW concept and strategy. Aircraft are increasingly becoming interoperable with sensors and command-and-control systems. Aircraft such as the JSF and the UAV/UCAVs will become components of the overall US designed and built defense architecture. The impact of this will flow on to US allies and friends who will increasingly align their defense industries with US companies and adopt US training methods, doctrine and associated weapon systems. This interoperability will extend to special mission aircraft such as AEW&C (AWACS) and JSTARS (or MC2A).

The industry is expected to see continued consolidation and certainly increased collaboration as companies such as Boeing (UCAVs), Lockheed Martin (Fighter aircraft) and Northrop Grumman (systems integration and NCW) continue to adopt a more specialized niche for themselves in the market. The success of the JSF and failure, to date, of a number of worldwide indigenous fighter and delays in worldwide transport programs, highlights the continued demise of indigenous programs. While Europe is currently competing in the fighter market with aircraft such as the Eurofighter, Gripen and Rafale, it has no follow-on fighter proposed or under development. Similarly, the protracted development and marketing of transport aircraft such as the A400M highlight the stranglehold the US will continue to hold in the market. Increasingly, foreign companies will continue to align themselves with US companies to share development and production costs. Overall, the US will benefit from a strong national security strategy, increased defense spending and a range of technically advanced platforms and systems.

ROTORCRAFT

For the past decade, the World helicopter industry has been a tale of two continents. While U.S. helicopter production has been dormant, the European helicopter industry experienced a period of growth and increased industry consolidation. Although helicopter production started to level off in the late 1990s, global terrorism sparked renewed interest in aviation across the board. The prospect of increased aviation procurement and R&D funding is expected to provide a degree of stability in the industry, and this will allow helicopter manufactures to pursue promising rotary wing technology – composite, tilt rotor, remotely piloted vehicles, and canard aircraft.

Traditional rotary wing markets – military, law enforcement, medical evacuation and energy exploration/exploitation – sustained the helicopter industry over the past decade, and now it appears that the civil rotary wing sector is about to enter a period of recovery.

Current Conditions. The helicopter sector is highly competitive and consists of five major producers that account for over 94% of the industry's market value: Sikorsky, Bell Helicopter, and Boeing in the U.S., and Agusta Westland and EADS Eurocopter in Europe. Sikorsky, a subsidiary of United Technologies Corp, produces and supports a range of military (UH-60 and CH-53) and civil helicopters (S-70 and S-76), and is developing a large transport (S-92) helicopter for both markets. Bell Helicopter, a subsidiary of Textron Industries, is the only North American manufacturer that claims to produce an even balance of military and commercial rotorcraft.[52] Bell produces a family of rotorcraft for the commercial market, with

both single and twin turbine engines, which fit in the light to medium category.[53] For the military, Bell is currently remanufacturing the UH-1Y and AH-1Z utility and attack helicopters for the USMC, and is co-developer of the V-22 tilt-rotor aircraft with Boeing Aircraft. Bell recently teamed with Agusta Westland on a commercial tilt-rotor (BA-609) for the civil market. Although it appears that Bell has staked its future on tilt rotor technology – clearly they have focused their R&D resources on developing this new, cutting edge technology – the company is also involved and committed to conventional rotorcraft.[54]

The Boeing Company, through their new Integrated Defense Systems division, produces military transport and attack helicopters. Specifically they remanufacture the heavy lift CH-47 Chinook for the US Army and some international customers. They are remanufacturing the AH-64 Apache multi-mission combat helicopters under a multi-year contract with the Army. They are also teamed with Sikorsky Aircraft to design and build the RAH-66 Comanche armed reconnaissance helicopter. Finally as discussed above, they are partnered with Bell to produce the V-22 tilt rotor for the U.S. Marines and U.S. Special Forces. Boeing has managed to secure a piece of the only 2 new manned rotorcraft development contracts (V-22 tilt-rotor and RAH-66 Comanche) that have been awarded by the U.S. government in the past 10 years.

Bell and Boeing are co-developers, in partnership with DARPA and the U.S. military, of the V-22 – the only tilt rotor aircraft, military or civilian, currently in production. The V-22 has emerged from the DoD directed pause in production and flight tests, imposed because of two major accidents that killed 23 Marines. DoD completed a comprehensive program review – engineering and mission needs – that identified several critical but correctable deficiencies. The V-22 program was continued on condition that several critical aircraft sub-systems – flight controls, rotors/propellers, hydraulics and system software – successfully complete rigorous flight evaluations. The flight evaluation is ongoing and current results are promising.

Agusta Westland and EADS Eurocopter each have strong entrants in the light to medium lift categories. Agusta Westland also teamed with Lockheed Martin to market the EH-101 and signed an agreement with Bell Helicopter to manufacture and market the EH-101 in the U.S. as the US-101. This aircraft will be a significant competitor to the S-92.

The rotorcraft industry can be characterized as technologically mature but structurally unstable due to overcapacity in its manufacturing sectors. Consolidation and / or teaming arrangements in Europe have greatly reduced the number of European competitors. Such consolidation has resulted in a trend of growing profitability. Most notable, GKN's Westland and Finmeccanica's Agusta merged in 2000 and the merged operation proved to be a genuine success for the two previously struggling manufacturers. With a forecasted market share of 13% of the world market, the combined company managed to become a viable world competitor with their EH-101 helicopter.

France, Germany, Italy, the Netherlands and most recently Portugal also established a cooperative agreement to further boost their presence in the helicopter industry. In this case, with the NH-90, a high-tech helicopter jointly developed by Agusta (Italy), Eurocopter (France and Germany), and Fokker (Netherlands) under the guidance of a new parent company, NH Industries (NHI), and NATO Helicopter Management Agency (HAHEMA). The NH-90 has captured the majority of the NATO light-medium lift market. NH-90 is the largest joint helicopter program ever launched in Europe with nearly 400 aircraft orders and with a forecast of potentially reaching 600 aircraft. The NH-90 was also selected by Norway, Sweden and Denmark for the Nordic Standard Helicopter Program.[55]

Other countries such as Russia, Japan, Malaysia, India, South Africa, and China produce rotorcraft, but are not significant global competitors.

Challenges. The world rotorcraft industry faces numerous major challenges. The first challenge is over-capacity. Although several European helicopter companies have merged and are reaping the economic benefits of the consolidation, the U.S. helicopter industry has not moved beyond limited joint ventures and co-production arrangements. Consequently, U.S. companies seem to have surrendered market share and are losing opportunities for technological advancements. Recently several senior members of the U.S. government and military challenged the U.S. industry "to lead in rotary wing technological development or surrender this vital area to the Europeans".[56]

The second challenge is the high and rising cost of tort insurance. As outlined in the February issue of Rotor & Wing International, "Insurance premiums for commercial helicopter operators have increased by 100-300%… the 15 major insurance companies that existed 20 years ago has been reduced to 5."

The third challenge is in the area of regulatory problems, safety and lagging infrastructure. The regulatory issues concern noise and the lack of flight rules that recognize the unique capability of rotorcraft flight. Rotorcraft noise issues have gotten so bad that many community's have banded together to fight the establishment of helicopter transit routes and heliports anywhere near their residential properties.[57] Public perception that rotorcraft flights are not as safe as fixed wing aircraft fleets must also be overcome. The goal should be to make rotorcraft flight as safe or safer than jetliner flight. Finally, the area of lagging infrastructure is concerned with instrument landing-capable helipads that facilitate transport to convenient locations in any weather. Being forced to take off and land at centralized locations or only at airports negates much of the convenience and timesaving advantages of rotorcraft flight.[58] Addressing these problems of regulatory issues, noise, safety and infrastructure are vital to achieve an increase in the civil market by expanding the rotorcraft transport mission. Resolving these issues will be particularly important when (and if) commercial tilt rotors begin production.

A fourth challenge is research and development (R&D) funding. Although the declining R&D investment trend of the past 10-15 years has leveled off, it is too early to tell if recent increases in U.S. government R&D funds, for tilt-rotor aircraft in particular, will migrate to other parts of the rotary wing industry.

Outlook. The rotorcraft market is expected to grow modestly over the next 10 years. The growth will be fueled by increased military sales while the civil market is projected to be relatively flat over the same period. Assuming the V-22 and RAH-66 programs are not reduced or cancelled, the ten-year projection (2002-2011) for industry sales of new and remanufactured rotorcraft is 9,237 rotorcraft, worth $74.8 billion. This includes 4,570 civil rotorcraft worth $12.5 billion, and 4,667 military rotorcraft worth $62.3 billion.[59]

In an effort to increase helicopter sales, manufacturers are pursuing the concept of helicopter fractional ownership for the civil market, emphasizing the need for increased government support for R&D, and focusing on a new area of operations – Para-public. Fractional ownership, which is a cooperative ownership arrangement, will make rotorcraft more affordable to business thereby increasing total sales, as was the case with fixed wing fractional ownership programs. Due to the limited range of helicopters and the regional orientation of their operators, future success in this emerging market will depend on the extent to which helicopter manufacturers can team with established business jet fractionals. Although there is no uniform definition for Para-public, it is generally understood to cover that part of the government operated helicopter sector that is not identified as Department or Ministry of Defense, i.e. the U.S. Coast Guard, Border Patrol and municipal police organizations.

The greatest competitive advantage the U.S. rotorcraft industry will enjoy in the coming decade rests on tilt rotor technology. Despite uncertainties surrounding the V-22 program, the

U.S. Marine Corps remains fully committed to fielding the aircraft. Indications are that the U.S. DOD will likely approve the V-22 for full-rate production. Bell estimates that combined military and civil tilt rotor aircraft will account for over 50% of its sales during the next ten years. Support and procurement of tilt rotor technology by the U.S. government is vital for the domestic rotorcraft industry to maintain its competitive advantage in this promising new market.

The Bell/Augusta joint venture to develop and produce an 8-10 seat civil tilt rotor, the BA-609, is proceeding on course with its' first successful flight test in 2003. Over 80 BA-609 orders from customers in 18 countries have already been received; however, the BA-609's future is inexorably linked to the V-22. As the technological development of the V-22 will undoubtedly be the basis for certification and regulation of this important new aviation sector, continued U.S. government support to the V-22 is vital. If FAA certification of the BA-609 is delayed, and operational rules governing its use are not implemented in a timely fashion, the aircraft will be grounded upon delivery and current and future sales will be jeopardized.

Despite the problems encountered during the development phase of the V-22, its tilt rotor technology has been shown to provide significant military utility. As a result, the U.S. military is showing increased interest in a heavy-lift, four-engine "Quad" tilt rotor concept. In July 2000 the Defense Advanced Research Projects Agency (DARPA) awarded Bell a contract to study feasibility of a "Quad" tilt rotor design with capacity similar to the C-130. Bell hopes to construct a prototype aircraft in the near future and believes that a production aircraft could be fielded as early as 2010. Considering fiscal constraints and the history of the V-22, we believe this prediction is overly optimistic.

The European Union's Fifth Framework Program had originally established a technology research program to develop a European tilt rotor aircraft. However, it appears now that both the European manufacturers and governments will not follow through on the initiative. They determined that development of this technology would be too costly. Beyond the minimal investment of Agusta Westland in the BA-609 with Bell, the European manufacturers are willing to wait and see if this new technology can be made safe and profitable. The lack of a European military requirement for a tilt rotor aircraft, and continued military investment in conventional helicopters serves to dissuade the development of costly tilt rotor technology to challenge the U.S. lead.

Although the prospects for conventional rotorcraft are improving, we believe this technology has reached its limit, and sustained long-term growth in the rotorcraft segment will depend on the viability of tilt rotor and other new technologies such as canard rotor wing aircraft.

Now that tilt-rotor technology is maturing and tilt rotor aircraft have by and large, demonstrated the ability to withstand the rigors of everyday flying, continued development of this important technology seems assured. Tilt rotor aircraft are a perfect fit for emerging roles in the military and law enforcement operations; and, it stands to reason that these aircraft will continue to be refined to fill specific roles, such as aerial intelligence and surveillance platforms. Civil tilt rotor aircraft will also evolve and meet the increasing demand for point-to-point travel (city center to city center). Business and corporate flight departments will eventually opt for the convenient and time saving travel that tilt rotor aircraft will offer, which will translate to viable tilt rotor airlines and fractional ownership programs.

JET AIRCRAFT GAS TURBINE ENGINES

Four major companies (the "Big Four")—General Electric Aircraft Engines (GE) and Pratt & Whitney (P&W) of the United States, Rolls-Royce (R-R) of the United Kingdom, and Societe Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA) of France—continue to lead the aircraft engine sector. In terms of jet aircraft turbine engine production and

sales, the sector leader is GE followed by P&W, SNECMA, and R-R respectively. In recent years highlighted by the 9-11 terror attacks, the aircraft industry as a whole entered what now appears to be an extended downturn. The jet aircraft gas turbine engine sector has also suffered. In the past, during downturns in aircraft engine sales, engine manufacturers could usually count on spare part sales and after-market maintenance, repair, and overhaul (MRO) agreements to provide sufficient profit margins. In fact, spare parts and MRO always provided more profit margin than the engines they supported. However, during this most recent downturn, spare parts and MRO profit margins have suffered.

Current Condition. The jet aircraft turbine engine market currently faces the following dynamic factors and conditions: (1) flat or low-growth defense budgets, (2) flat or declining commercial/civil sector budgets, (3) highly competitive commercial and defense markets, and (4) unpredictable international markets.

Aircraft engine production and sales in general are directly tied to commercial and military aircraft production and sales. Demand for spare parts and services are also critical sources of revenue in the jet aircraft turbine engine sector. Military aircraft sales and corresponding engine sales are expected to increase in 2003 and over the next ten years, while commercial sales decrease. In the U.S., the events of 9-11, the Global War on Terror (GWOT), and Operation Iraqi Freedom have increased DoD funding. However, despite increases in post 9-11 U.S. defense budgets, the majority of defense budgets around the globe are flat or low-growth. In addition, aircraft engine manufacturers are currently being pinched hard by the aircraft industry downturn. "The gas turbine sector has also been hard hit. New orders are becoming increasingly scarce and the competition is eating up whatever slim profit margins formerly existed in turbine sales."[60]

Commercial transports powered by large gas turbine engines dominate the market—led by large commercial jetliners. Therefore, large turbine engine sales outpace small turbine engine sales and are more profitable. However, the large turbine engine sector is currently weak due to declining commercial air travel and flat civil budgets. As a result, there is over-capacity in the sector that the industry will not be able to absorb.

The current commercial airline and aircraft "bear market" is also leading the "Big Four" to engage in more partnerships with each other and with smaller engine manufacturers than has been the case in previous years. Business jets have been surprisingly active, with the lowest end of the business jet sector experiencing the most activity as aircraft manufacturers try to push into the top end of the corporate turboprop market. However, after five years of remarkable growth, the business jet market has effectively stalled, raising fears of how deep and how long the downturn will be.[61]

Small turbine engines have fared better in the downturn than the large turbine sector. The less-than-150-seat passenger aircraft market utilizes small turbine engines, and is enjoying robust sales. This and current military aircraft procurement means more new developments for the small turbine engine sector. Small turbines are one of the few areas of new turbine development.[62] However, very few fighters are being produced today—three in the U.S. and three in Europe—causing tough global competition. For the next several years, strengths in the small turbine engine sector are expected to continue to come from increased sales of military fighter aircraft, including an expanding market for multi-year procurement of the F-35 (JSF), F/A-22 and F/A-18E/F aircraft, and continued foreign military sales of F-16s. European nations are developing the Eurofighter (Typhoon), Gripen, and Rafale fighters. These few fighter programs increase already stiff competition and limit engine manufacturers' new turbine engine possibilities. One example of this is the uncertainty as to whether the U.S. will choose only one engine for the JSF or two—in order to keep both GE and P&W in the game. The implications of

this pending decision will have major impacts on the losing engine competitor's future capacity.

International markets for jet aircraft turbine engines are less predictable than ever. Due to over-capacity, the events of 9-11, the ensuing GWOT, Operation Iraqi Freedom and SARS, the industry is in unpredictable turmoil.

One bright spot for engine manufacturers is the increasing design and development of unmanned aerial vehicles (UAV). This development will result in increased sales of small gas turbine engines. Global interest in UAVs continues to increase, and industry analysts predict that the UAV market will continue to expand faster than most other sectors of the aerospace industry. One significant trend is the development of larger UAVs such as Global Hawk and uninhabited combat air vehicles (UCAV's). These aircraft will require larger engines. In addition to the U.S. and Israeli programs, the European UAV program is also rapidly expanding, presenting a much larger potential market for small turbine engines in the future. "Although the UAV market is expanding, there are questions about the pace of expansion, the regional dimensions of UAV utilization, the pace of deployment of new types of UAVs and the actual market size of UAV production."[63] Despite several positive conditions, the jet aircraft turbine engine sector still faces several challenges.

Challenges. The jet aircraft turbine engine sector faces four primary challenges. First, the major challenge facing engine manufacturers is strong competition. Orders and sales of jet aircraft engines, spare parts, and services are competitive and cyclical. Competition between the "Big Four" has significant impacts on corporate profit margins and engine manufacturers are constantly striving to increase profitability. However, profit margins from engine sales for all engine manufacturers are currently, and historically, low. While airline and aircraft business and profit margins decrease, new applications for the future are also decreasing. This could signal significant trouble ahead for the gas turbine engine market. Commercial sales and orders have proven to be harder to predict than military sales and orders. Commercial aircraft sales are subject to the health of the airline industry, which is currently very unhealthy. As a result, the threat of order and backlog postponements and/or cancellations continues to plague aircraft and engine manufacturers. There are absolutely no guaranteed sales, despite contracts and agreements with customers to buy aircraft and engines. Sales, orders, backlog, production, and shipments have all declined and are forecasted to continue declining. Even the once rapidly growing regional jet (RJ) market is suffering. The RJ market was hit by a double loss with the cancellation of BAE's RJX program and the financial collapse of Fairchild Dornier.[64]

The military market appears to provide greater potential for aircraft engine manufacturers than does the commercial market. The U.S. is the largest flyer and buyer of military aircraft. Also following the U.S. and the changing geo-political environment, China, India, Russia and the European Union (EU) are increasing their defense expenditures.[65] Military sales are expected to increase over the next ten years; however, the current and projected increase in military sales will not be enough to offset the decline in commercial sales.

In spite of the short-term health of the military side of the industry, the long-term prospects for military engines are not promising.[66] Government demand is uncertain. One real challenge for the military engine sector is the inevitable, unsustainable pace of current U.S. defense spending. Constraints on U.S. and international defense spending will come into play in the coming years as nations around the globe feel the impact of the current global economic downtown. Not even the world's richest countries—including the U.S.—will be able to keep defense spending at current levels indefinitely. As a result, MRO and parts profit margins will suffer. This is significant because engine manufacturer sales of parts and MRO has always been their main profit source, with margins of around 40% on spares and 5-10% on MRO.[67] MRO revenues play an increasing important role in airline sustainability as airlines are increasingly

turning to maintenance providers to take the lead in best-practice initiatives and profit-center development.[68] Engine manufacturers plan to fight the competition and enhance profits margin through spare parts and long-term, comprehensive customer support and MRO agreements.

Second, in recent years, low profit margins on engine sales have prompted engine manufacturers to implement cost and risk reduction initiatives. The highly competitive engine market is pushing companies to increase efficiency, consolidate operations, develop innovative marketing approaches, improve performance, refine production techniques, and implement new management systems in order to improve their competitive advantage.[69] Unlike other spheres of the aircraft industry, development in the engine sector has been progressive and sequential. As long as the bulk of the planes keep flying in the atmospheric layer, the present principles of propulsion will remain valid and no foreseeable revolution is on the horizon.

Third, R&D costs are high—especially for large turbine engines. In spite of costs, the "Big Four" realize they need to increase investment in R&D. However, capital investment in R&D has decreased as a result of lower profit margins and reduced government funding for R&D. In order to reduce R&D costs and risks, many new engines are simply re-designed improvements of existing families of engines while new partnerships have formed to share costs, share expertise, share processes, reduce risks, and gain or expand access to international markets. As a result, in order to optimize R&D and to restrict user's choices, the four major manufacturers are already working on joint projects. In addition, R&D and new technology development for military aircraft engines is complementing new product development for the commercial sector.

Finally, in addition to manufacturer collaboration and R&D programs, several important *market factors* present challenges that are stimulating significant improvements in engine technology. The primary factors are: (1) customer requirements for safe and reliable engines, (2) customer requirements for improved fuel efficiency, (3) customer requirements for increased thrust and performance, (4) environmental requirements for quiet and low-emission engines, and (5) manufacturer requirements for increased profitability through competitive advantage.

***Outlook*.** New generations of aircraft and bourgeoning markets provide hope for the future. In the commercial sector, aircraft like the Airbus A380, new 7E7, and newer versions of existing Airbus and Boeing models are on the horizon. According to one estimate by R-R, this pattern of induction in the next twenty years would create a demand for 70-75,000 engines.[70] Even if this prediction is reduced, the demand should be sufficient to keep the industry stable after current SARS fears die down. In spite of a slump in the U.S. airline market, Asian routes will continue to absorb a significant number of aircraft. Also, despite recent setbacks, 60 – 100 seat aircraft are gaining ground in global markets. RJ aircraft are expected to overshadow the smaller jets and turboprops and the demand for engines for such aircraft will correspondingly increase. Several functional and structural changes in airlines, a reduction in global terrorism, a short war in Iraq and the expected recovery of the global economy are all likely to stimulate the industry to further strengthen the commercial sector as economic globalization and an increase in population continue to enhance the demands for air transportation. In the military sector, several new aircraft procurements and service-life extension programs are on the horizon. In addition to new fighters, another major dimension will be the extensive U.S. tanker lease program, further enhancing the demand for new engines.

For the large turbine engine sector, R-R and SNECMA will continue to dominate the European market. Both firms are expected to not only remain profitable individually, but in partnerships also. They will compete for their share of Airbus and Boeing commercial and military aircraft projects, including the A380. R-R forecasts increasing the share from 35-40% of the expected 71,000 engines is likely to be in demand up to 2020.[71] R-R's success will come from its Trent family of engines, especially the Trent 500 (sole engine for the A340) and the

Trent 900 currently under development for the A380. R-R appears better positioned for future success than does SNECMA, whose major success will continue to come from its world-leading CFM-56 engine co-produced in joint venture with GE. In the U.S., GE and P&W will continue to dominate. GE seems well positioned to remain the largest aircraft engine manufacturer. GE's revenue rose by five percent in 2002 to $131.7B.[72] Their major success is the GE 90-115B engine for the Boeing 777-200LR/-300ER. This engine is the first of a new generation of engines being designed and tested to tougher standards that should enable operators to move beyond the current limitations governing extended twin-engine operations overwater (ETOPS).[73] P&W's major success is in its military engines. P&W has also formed a joint venture with GE for the production of modern technology engines for high capacity long-range aircraft. If this alliance pays dividends in the GP-7200 engine for the A380, future application of such strategies are expected. In addition, world air cargo growth will expand in the next two decades creating new demand for jet engines. During the next 20 years, the world freighter fleet will grow at a slower rate than previously forecasted but nevertheless will expand to nearly 3,100 units by 2021.[74] The eventual resurgent sales of large Boeing and Airbus jetliners, military tanker aircraft, and both military and commercial cargo aircraft provide future growth opportunities.

For the small turbine engine sector, recovery from the current downturn will be less predictable than ever. In spite of the inherent unpredictability of the commercial and military—particularly fighter aircraft—markets for small gas turbine engines beyond current developments and applications, engine manufacturers must be positioned to capitalize on their strengths and to take advantage of potential opportunities on the horizon. The F/A-22 and JSF programs will be beneficial to the U.S. engine manufacturing industry. Not only has the R&D contributed to improvement in commercial engines, but also the potential sale of 6,000 – 8,000 combat aircraft power plants over the next two decades will provide financial stability, thus creating sufficient recovery potential and breathing space in the aftermath of the recent downturn in the industry. However, the F/A-22 program is very costly and not yet approved for international sales, while JSF may very well be the last manned fighter program on the globe. In addition, it is possible that JSF will kill Europe's Typhoon, Gripen, and Rafale efforts to gain international sales. The JSF program holds the most promise for both GE and P&W, and will have a major impact on both company's future in this sector. P&W's F135 engine will be the first engine on initial lots of the JSF, but faces future head-to-head competition against GE's F136 engine. If the JSF program goes solely with P&W's F135 engine, the results will likely force GE to get out of military fighter engine production. In the coming years, increased emphasis will also be placed on the use of UAVs, UCAVs, and cruise missiles. The UAV, UCAV, and cruise missile markets are huge targets of opportunity for small turbine engine manufacturers, as is the airlines' recent shifts to move from turboprops to turbofans in RJ and business jet markets. In the years ahead, turboprops are expected to loose considerable ground to small turbofans, and will eventually be restricted to small 30 – 40 seat and special RJ aircraft.

Low profit margins will continue to underscore engine manufacturer's emphasis on providing total customer solutions with product spares and MRO agreements. Maintenance of existing engines will continue to be a major issue. Higher safety standards and more flying hours per day will warrant a much-enhanced degree of maintenance. Due to sophistication of technology, maintenance has become more complex and specialized; therefore, the engine manufacturers have also become involved in backup support. As parts become very complicated and of precision quality, their supply will be restricted to Original Equipment Manufacturers.[75] Therefore, GE has developed a web-based maintenance system and expects to have 300 customers for its Customer Web Center by year-end and to have $1B in orders by the beginning of next year. Similarly, R-R launched the first trial of its new maintenance portal, Aeromanager,

at Farnborough. R-R has 45% of the current production commercial engines and 25% of its corporate jet customers enrolled in its Total Care package. P&W and SNECMA have similar support packages. The challenge for engine OEMs will be to survive aggressive campaigns by after-market service providers to take MRO service away from OEMs. As a result, OEMs may look to acquire smaller after-market service providers as customer support packages and MRO agreements become increasingly important to airline sustainability and engine manufacturer profitability. Spares will be key to OEMs' revenue, providing as much as 50% profit margins.

The "Big Four" aircraft engine manufacturers will continue to dominate the market. Strategic partnerships through alliances and joint ventures will become the norm rather than further consolidation. Examples of current partner relationships are CFM International (GE and SNECMA, International Aero Engines (P&W, R-R, MTU Aero Engines, and Japanese Aero Engines Corporation), GE and Honeywell, GE and R-R, and the GE/P&W "Engine Alliance." As the commercial market rebounds, additional partnerships are still likely and multiple partners will likely share new projects and product development. Despite future threats and challenges, the sector will likely remain profitable. In addition, the "Big Four" are not only in good financial health, but also optimistic about the future prospects. The highly competitive jet aircraft turbine engine sector will continue to provide top quality engines and capacity will be pared down to appropriate levels in comparison to the present and projected demand. Profit enhancement will be tied directly to engine manufacturers' abilities to reduce costs and mitigate risks.

CONCLUSION

Despite continued September 11 traveling concerns, and the current SARS fear, the U.S. commercial aircraft industry remains a strong component of American national power. On the commercial side the worst seems to be passing. Airline mergers and bankruptcies along with an attendant buildup of "parked" aircraft in desert storage will continue to take their toll on aircraft industry profitability for the next two to four years. But the industry has powered through this low point with amazing flexibility.

The U.S. aircraft industry has weathered the storm by turning to lucrative military sales, and logistic service contracts. While the commercial sales have waned, military build-up along with a call for transformational technologies (such as Unmanned Aerial Vehicles and tilt-rotor technology) have given the U.S. aircraft industry a needed boost…and has left European competitors scrambling to get a piece of the U.S. military business. In addition, aircraft companies on both sides of the Atlantic have discovered the service side of their businesses. Selling spare parts, training and existing equipment service has become a core business strategy for all companies visited.

While U.S. industry makes a leap towards better profitability, there is no company that has come through the recent market trials unscathed. This industry shake up has caused all companies to become much more lean. All businesses we visited have seen layoffs, and have incorporated lean practices and IT services in a big way. The recent market woes have also caused them to reassess their core competencies and decide on their respective niche markets. Lockheed Martin Corp has captured a large part of the manned fighter market, so Boeing has shifted emphasis to UAV's. Sikorsky is concentrating on a traditional heavy lift helicopter, while Bell/Boeing concentrate on the tilt rotor concept. Boeing commercial is concentrating on the narrow-bodied 7E7 while Airbus moves in the direction of a super jumbo jet. In 2003 and for the foreseeable future, the aircraft industry will be very selective of the products they market, the services they provide and the customers they court.

It is becoming clear that in order to grow their businesses the aircraft industry players will have to partner with others to gain additional market share. For example, even the largest

European companies such as EADS see the absolute certainty of never breaking into the U.S. military market without teaming with U.S. industry. Though never openly mentioned, it was clear that they also fear that the stance of their collective governments against U.S. diplomatic and military actions abroad will also affect their U.S. sales of both military and commercial products. One way to counteract that would be teaming with a major U.S. defense contractor to give them an American "face."

The U.S. aircraft industry has come through a tough time more refined and leaner. It remains competitive and capable of meeting current national security requirements. The devalued dollar will make U.S. aircraft exports more enticing in the near term. Nevertheless, significant recovery in the commercial aircraft sector probably will not occur until late 2005. Finally, a combined effort by both industry and government are required to preserve and enhance this vital U.S. industry—so crucial to our national security.

Additional Essays

Aircraft Safety and Security, US Department of Transportation, Federal Aviation Administration

LTC Byron Cherry, USA and LtCol John Wassink, USMC
Mr. James Yacobi, DOT, Faculty Advoisor

The Federal Aviation Administration commissioned the Industrial College of the Armed Forces to conduct research to identify and analyze functional and operational relationships between aircraft security and aircraft flight safety. Research involved discussions with major aircraft and engine manufacturers in the United States, United Kingdom, and Sweden, extensive travel through national and international airports, and comprehensive library research on potential threats, current airport security procedures, technologies available to enhance aircraft safety and security, and additional security measures initiated following the events of September 11, 2001.

Currently, market forces will not drive the aircraft manufacturing or air travel industries towards enhancing aircraft safety and security. Aircraft manufacturers are striving to increase aircraft efficiency and decrease production costs in an effort to remain competitive in a sluggish market. Airlines and airports are striving to reduce operating expenses in an effort to reduce travel costs and generate flight demand. Investments in safety and security are counterproductive to both these efforts.

Recent actions to increase safety and security following the events of September 11, 2001, such as federalizing airport security and hardening aircraft cockpit doors, required extensive federal assistance. The total costs of the September 11, 2001 attacks, not only to the aircraft and air travel industries, but to the overall United States' economy mandates this investment. Future technologies, specifically in the fields of biometrics and positive personnel identification as well as automated aircraft control systems have potential to further reduce the likelihood of unauthorized personnel gaining access to an aircraft on the ground or seizing effective control of an aircraft in flight. However, research and development in these efforts will not be taken voluntarily by the aircraft industry, especially in the current depressed travel market. This study concludes that federal intervention and funding, along with close cooperation between the Federal Aviation Administration and the aircraft industry, will be necessary to generate additional technological and procedural solutions to enhance aircraft safety and security.

Aircraft Industry Study Analysis of Supply Chain Management for the Defense Logistics Agency, Defense Supply Center Richmond

Lt Col James Hannon, USAF and Mr. Stacey Strayer, Department of the Navy
CAPT Stephen Morris, USN, Faculty Advisor

The ICAF Aircraft Industry Study (AIS) conducted research on commercial and foreign aircraft industry Supply Chain Management (SCM) practices; specifically to identify "world class" supply chain relationships in the supply and/or manufacture of replacement aircraft parts and equipment. The paper reviews the basic tenants of SCM, and summarizes how the original equipment manufacturers (OEMs), as well as 2nd and 3rd tier suppliers, from both foreign and domestic segments have developed or incorporated these process characteristics especially as they relate to long-term support of aging aircraft in the after market environment. The study further addresses how these segments identify and groom new/additional sources for parts/components, deal with the issue of intellectual property of vendors who have exited the market, and support "On Demand Manufacturing" requests. The study also includes analysis of key process characteristics to demonstrate which are most suitable for use within the DoD and concludes with recommendations for implementation.

AF/XPX Tanker Study

LtCol John Norton, USAF and Mr. Robert Marx, Ph.D., DAF
Lt Col Carl Rehberg, Ph.D., USAFR, Faculty Advisor & Editor

An ICAF Aircraft Industry Study (AIS) team conducted research on options for USAF tanker recapitalization, on behalf of Air Force Strategic Plans, AF/XPX. The analysis reviewed follow-on options to the presumed lease of 100 Boeing KC-767 tankers. The study showed that the current USAF plans will NOT get the tanker fleet well by 2020. The study recommended a mix of aircraft with new operational constructs as the way to meet those needs. Some of their most critical primary recommendations included: 1) Develop a Modular Universal Boom as a transformation enabler; 2) AF/DoD participation on 7E7, 737NG2, and 747X design teams; 3) Develop 747-400 and BBJ tanker conversion prototypes; 4) Provide ~15-25% of wartime AR capability from innovative options; 5) Develop multinational tanker units in Europe and the Pacific. 6) A number of follow-on or additional studies in vital areas. The study deliverables were a 80 page paper (including appendices) and a companion PowerPoint briefing.

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